IDA DOCUMENT D-1292

ADA COMPILER VALIDATION SUPPORT: FISCAL YEAR 1992

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December 1992

Prepared for
Ada Joint Program Office

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Task T-D5-304

PREFACE

The issue analysis and resolution process for Ada compiler validation was requested by the Ada Joint Program Office (AJPO), under the Institute for Defense Analyses (IDA) Task, Ada Validation, as an on-going part of the Department of Defense's Ada language control program. The issues resolved during fiscal year 1992 are the subject of this report which is a partial fulfillment of this task.

Special thanks are due to Ms. Christine Anderson, Ada 9X Project Manager, for her efforts to bring the economic and procedural concerns of compiler vendors to the attention of the Ada Board and participants in the Ada validation process. Also, thanks are due to members of the Fast Reaction Team who conscientiously gave of their time to assist IDA with the analyses and resolution of complex language and compiler implementation issues: Dr. Robert Dewar (New York University), Dr. John B. Goodenough (Software Engineering Institute), Dr. Norman Cohen (IBM), Dr. Stephan Heilbrunner (Salzburg University), Dr. Erhard Ploedereder (Tartan Laboratories), Dr. Brian Wichmann (National Physical Laboratory-UK), and Dr. Kenneth Dritz (Argonne Laboratories). The IDA reviewers of this report were Dr. Dennis W. Fife, Dr. Cy D. Ardoin, and Dr. Richard L. Wexelblat.

EXECUTIVE SUMMARY

The Ada Joint Program Office (AJPO) has tasked the Institute for Defense Analyses (IDA) to conduct on-going analyses of the Ada compiler validation policies, procedures, and conformity test programs. During fiscal year 1992, validation policies were the primary area of concern among compiler vendors anticipating the requirement for significant capital investment in Ada 9X compilers. Several proposals for policy change were made by the Ada Board, a Federal Advisory group, who advise the AJPO Director on a wide range of Ada Program topics. IDA participated in the process of resolving issues raised by Ada Board proposals and other issues raised by DoD and non-DoD organizations. IDA analyzed these proposals for technical and procedural implications. Recommendations for the Director, AJPO, were based upon IDA's analysis and comment from various individual experts and organizations having an interest in conformity testing. This report summarizes the issues that had a bearing on policy changes incorporated in a revision of the Ada Compiler Validation Procedures produced by IDA and published by the AJPO in August 1992. These policy changes include:

- A time-limited (one year) provisional validation status for a compiler vendor who fails a small number (ten or fewer) conformity tests.
- Designation of the Ada Compiler Validation Capability (ACVC) test suite version 1.11 as the final version for testing compilers that implement the 1983 version of the Ada language.
- Guidelines for DoD software project managers on configuration management of an Ada compiler over the life of a software development project.

IDA also maintains a current and historical data base containing pertinent information about technical issues raised by compiler vendors who are using the test programs contained in the ACVC. This report also summarizes the disputed tests and the rationale for resolution of them that was entered into this data base during fiscal year 1992.

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1. INTRODUCTION

The Ada Joint Program Office (AJPO) has tasked the Institute for Defense Analyses (IDA) to provide independent analyses of the Ada compiler validation process and to assist in resolving technical and procedural issues that arise during the execution of the process. IDA provides a range of technical and policy analyses to support the AJPO, primarily acting as an arbiter of issues that could reduce the effectiveness of DoD's policy for the use of validated Ada compilers. Many interested parties provide comments on Ada compiler validation policies. IDA assists the AJPO in evaluating these proposals for potential policy change and in developing implementation procedures when a policy decision has been made. This report discusses the validation policy changes that have been incorporated in the *Ada Validation Procedures*, Version 3.1. There is also a summary of the test issues resolved through the Ada Compiler Validation Capability (ACVC) test dispute process.

This fiscal year summary of work performed on behalf of the AJPO was written for those who have an interest in recent validation issues and for those who will consider various policy proposals to align the current process with the requirements of the revised language and test suite known as Ada 9X.

2. BACKGROUND

During 1991 and 1992, compiler validation issues were raised by the Ada Board, the Services, and compiler vendors that resulted in policy changes in the current validation process. The resolution of issues concerning the present practices was decided by the Director, AJPO, and incorporated in a revised *Ada Validation Procedures* document published in August 1992. These policy changes generally provide economic benefits for compiler vendors in anticipation of their being able to invest resources in tools, performance improvements, and Ada 9X implementations.

3. POLICY ISSUES

This section summarizes the validation policy issues and actions taken to resolve them. The resolution of some issues concerning Ada 9X is still in progress as part of the Ada 9X project.

3.1 PROVISIONAL VALIDATION STATUS

Issue: *Validation costs can be reduced by changing the test dispute process and allowing a compiler to fail a small number of tests in the ACVC test suite.*

Several Ada Board members raised the issue of the cost borne by compiler vendors to dispute the correctness of tests in the ACVC. Because vendors are uncertain of the outcome of a dispute and how long it will take to get a resolution, some Ada Board members claimed that vendors do not bother to dispute tests but change their compilers to pass them. Often making these compiler changes diverts vendor resources from improvements that would benefit the user community.

The Ada 9X effort and cost to vendors to implement Ada 9X compilers became inextricably related to the problems of ACVC quality and the requirement that a compiler must pass all applicable ACVC tests as a condition for receiving a validation certificate. Several members of the Ada Board prepared a position paper for the Director, AJPO, in which they recommended that a vendor need not pass all ACVC tests to obtain a certificate because some tests are known to have marginal value. It was proposed that a vendor could dispute any test in the ACVC as being incorrect or pathological (i.e., the latter being a test for a language rule that is not useful in practice). Test disputes would be resolved by an extended process of deliberation by the International Organization for Standards Working Group on Ada (ISO WG-9) who would issue a resolution in due time without the pressure to adhere to an Ada Validation Facility (AVF) contract schedule for validation. The Ada Board paper suggested that IDA's role should be limited to withdrawing ACVC tests that contain obvious errors and resolving test issues based upon precedent for resolutions. The arguments for an extended test resolution period were based on the view that a vendor should be allowed to have a certificate, even though some ACVC tests were failed, while

ISO WG-9 considers the merits of the dispute more thoroughly. The extended resolution period would not be constrained by a target date for issuing a resolution as is the case in the present resolution process. At the end of the ISO WG-9 deliberation period, if the test was judged to be both correct and useful, the vendor would be obligated to pass the test in future validations of that compiler.

Several benefits were expected from the extended resolution process. From an ACVC quality viewpoint, vendors would be assisting in the discovery of pathological tests. ISO-WG-9 could directly assist the Ada9X ACVC Team to avoid perpetuating similar tests in a new test suite. Finally, vendors could forego the cost of a dispute before obtaining a validation certificate and could use these resources for work on tools and Ada 9X compilers.

The Ada Board paper was distributed to AVF managers and IDA prepared a draft revision of the *Ada Validation Procedures*. The AJPO provided the DoD Senior Software Officials with these revised procedures for review and comment. Service and Agency comments provided little support for the Ada Board recommendations with vigorous objections coming from the AVFs. It was not clear to the reviewers why a change in policy was need for validating Ada 83 compilers (i.e., compilers validated under the 1983 Ada language standard) and others objected to the principle of issuing a validation certificate for a compiler with known errors. Yet the problem of how to reduce validation cost now so that compiler vendors could invest in tools and Ada 9X compilers remained an issue that needed resolution.

Resolution: IDA prepared an analysis of the Ada Board paper for the Director, AJPO that recommended a compromise position. The Ada Board's major concerns were providing economic relief to compiler vendors and improving the quality of the ACVC tests. The IDA "Strawman" proposal recommended the following:

- A compiler vendor should be able to complete a contracted validation process with not more than 10 failed ACVC tests, and that the compiler be re-tested within a 12-month period, and successfully pass the ACVC, to obtain a Validation Certificate.
- A compiler vendor should request, at any time, that ISO WG-9 accept a particular ACVC test for extended resolution. IDA will withdraw any test accepted for extended resolution so that all compiler vendors will be exempt from the test until a final resolution has been made by ISO WG-9.

- The current test dispute process should continue with the only modification being that a vendor need not have all disputes resolved before commencing the on-site testing process. A vendor may declare the failure of up to 10 tests and elect to obtain a provisional validation status while corrections are made to the compiler. If the vendor appeals to ISO WG-9 for the extended resolution process, a validation certificate may be issued if all the failed tests are accepted by ISO WG9. IDA will also withdraw the tests accepted for the extended resolution process so that no other vendor need dispute them.
- If a compiler vendor does not successfully pass the ACVC within 12 months, the provisional validation status expires.

The Director, AJPO, accepted the Strawman recommendations with an added proviso that a certificate of provisional validation status would contain the list of failed tests. A list of compilers that have provisional validation status and the identification of failed tests would be public information. Provisional validated status is a major policy change that should encourage compiler vendors to respond to market demand for new Ada compilers (e.g., new hardware architectures) with a grace period to appeal failed tests to ISO WG-9 or to change the compiler.

3.2 CHANGE IN THE TEST SUITE CONTENT

Issue: *The problem of validation costs is a continuing concern that is related to the frequency of change in the ACVC and the number of errors in each version.*

The conformity test suite for Ada 83 evolved over a ten-year period with new versions being issue every 6 months, at first, then 12 months, and finally, every 18 months. The life of a Validation Certificate was initially 12 months and was increased to be consistent with the 18-month ACVC release cycle. Each new version of the ACVC has contained new or changed tests which contain errors. For example, in ACVC 1.11 over 10% of the new or changed tests tests were withdrawn. Vendors claim that internal cost for configuration management of the test suite, pre-validation testing on all their compilers, and the research required to dispute a failed test far exceeds the formal validation cost of AVF testing. After initiation of the Ada 9X Project, vendors expressed concern about continuation of the 18-month version release schedule. The release schedule was extended to 24 months in 1990 but vendors challenged the need for new releases of a test suite for a language undergoing revision. Each new release would contain some tests with errors that could only be discovered after vendor resources had been expended to find them. The consensus among vendors

and users was that adding new tests would not only provide marginal benefits but could conflict with some Ada 9X revision goals.

Resolution: In the Spring of 1992, the Director, AJPO, announced to the Ada community that tests for validation of Ada 83 compilers had been frozen on version 1.11. Tests could be removed but no tests would be added or changed. There were few benefits, except to AVF revenue, by issuing a changed version of the test suite. Most of the incorrect tests had already been withdrawn by IDA, with documentation having been provided to the Ada 9X ACVC team and the Ada 9X ACVC reviewers.

The Ada 9X Project Office is committed to reduce the number of marginal tests by deriving tests that reflect the use of the Ada language. Although there is no objective measure of language use, the Ada 9X ACVC Team and ACVC Reviewers are investigating many sources of information concerning language use. It is recognized that the number of tests for similar objectives could be reduced by combinations of test code and analysis of the unique test cases that demonstrate conformity in a normative context. Exhaustive testing of all possible contexts is impractical. IDA continues to support the Ada 9X Project Office in resolving the issue of quality and cost containment for the Ada 9X ACVC.

3.3 UNDETECTED COMPILER ERRORS

Issue: *All validated compilers contain undetected errors. The conformity test suite should be concentrated on finding errors that affect the portability of programs produced by the compiler.*

The resolution of this issue is closely related to finding a reasonable language use basis for selecting ACVC tests but is more narrowly focused on deviations among compilers. ISO WG-9 does provide advisories to compiler implementers and users on potential deviations that adversely affect the portability of Ada programs. The Ada 9X language will provide guidance for the use of the language in certain user domains such as real-time, embedded systems, business systems, and safety critical applications. The Ada 9X ACVC will reflect the specialization these domains represent.

Resolution: It is too early to say whether the work of the Ada 9X Project and ISO WG-9 will provide test objectives for portability within specific user domains. The Ada 9X testing strategy will be different in some respects. Experience with the test suite will be needed to revise the *Ada Validation Procedures* appropriately and to arbitrate the test dispute process.

3.4 PERIODIC COMPILER REPLACEMENT

Issue: *It is impractical for DoD software project managers to replace an Ada compiler version just because its certificate has expired. Project managers should be given some practical guidance about how to comply with the Ada mandate.*

Managers of software development projects select an Ada compiler that has validated status but the life of validated status is tied to the expiration date of the certificate. Compiler vendors offer maintenance agreements that include replacement of the compiler with a newer version having a certificate. The replacement compiler may be different in some respects so that source code developed using the earlier version must be recompiled. Software managers prefer to select a particular version of a compiler for use during an entire development period. However, when the developing organization is ready to deliver the software to a maintenance organization, the receiving organization may refuse to accept the software because the compiler does not have validated status.

As more and more Ada systems are being turned over to the government or contractors for maintenance, DoD project managers and system program managers have petitioned the AJPO for adjudication of claims that the delivered code does not perform as expected because it was developed using a compiler that does not meet the literal interpretation of validated.The Services requested that the *Ada Validation Procedures* provide guidance to project managers on the use of the Ada compiler validation process. Non-DoD software development organizations objected to including guidance from DoD on the software development practices they employ.

Resolution: An appendix was added to the revised *Ada Compiler Validation Procedures*, Version 3.1, to provide guidance to DoD project managers. The guidance is based on configuration management practices to control and document changes to the compiler and re-testing of the compiler with the ACVC version used to validate the compiler. The results from this re-testing indicate the differences caused by compiler changes and identifies any resulting non-conformities. A project manager will determine what action, if any, will be taken to bring the compiler up to a current validated version. Maintenance organizations will also be provided with complete and current technical documentation of the compiler. Non-DoD organizations are not obligated to follow this guidance but may choose to incorporate some aspects in their procedures.

4. ACVC TEST DISPUTES

In fiscal year 1992, AVFs submitted over 40 petitions against ACVC tests. Most of these disputes were resolved by precedent but there were nine disputes that had not been raised previously. Among the new disputes, the principal issues addressed in this section are the meaning of "allowable value" with regard to representation of fixed-point types, the value for 'SIZE of a floating-point type implemented on unusual hardware, and the acceptable consequences of a bad floating-point-divide machine operation. Appendix A contains a more detailed discussion of these disputes.

The first dispute concerned whether a compiler could select a value for 'LAST for a fixed-point type and then reject a 'SIZE representation specification for that type that did not provide sufficient space to store that value, or must 'LAST be selected in accordance with the specified representation size. The Fast-Reaction Team (FRT) was generally opposed to the implementation and supported the tests but there was some dissent from a strong position against the petitioner. IDA analyzed the tests and noticed that they did not correctly test for the values 'FIRST and 'LAST. In consideration of this incorrectness of the tests, the divided opinion of the FRT, and the unclear wording of the Standard and Commentaries, the dispute was accepted. The implementer was cautioned that the tests were still considered to reflect the intent of the language and that the revised language (Ada 9X) would make a similar requirement.

The dispute concerning the appropriate value for 'SIZE for a floating-point type arose as a result of an unusual architecture that restricted access to the bits that held a floating-point value's exponent. This hardware allowed access to only 24 of 32 bits in each word for most operations; only floating-point operations use the full 32 bits. The FRT again reached no consensus. The dispute was accepted as the grounds for rejection were dubious and the consequences of this implementation's behavior were unlikely to affect users adversely.

The third dispute explored the extent to which a bad machine floating-point divide operation could cause non-conforming behavior. The FRT agreed that the implementation

of floating-point division in software would be a waste of effort, in that users would not want the inherent inefficiency. But the FRT was divided in whether to extend the acceptance of non-conforming behavior to the implementation's ASCII-to-float conversion routine, which itself used the faulty division operation; two FRT members argued that the implementer should work around the hardware problem just as users must do in applications. IDA accepted the non-conforming behavior on floating-point division as justified as per Commentary AI-00325 ("it is impossible or impractical to remove it, given the implementation's execution environment"); but IDA rejected the petition against the required ASCII-to-float conversion and required the ACVC test to be passed.

5. OTHER VALIDATION ACTIVITIES

One implementer requested that groups of ACVC test programs be combined into a single program so that compilation, linking, and downloading time would be reduced. IDA worked with the AVF to implement this special processing, which required that individual test programs be modified so that they could be included as subprograms within a enclosing program shell. IDA analyzed the ACVC in order to determine what test programs could be so modified without compromising any test objective. The effort was undertaken in part for the sake of assessing the benefit of such processing for validation in general; however, the AVF's essential job of collecting and grading results under some pressure to complete validation quickly precluded collecting comparative data on the effects of processing. Informal observations by the AVF and some of the implementer personnel led to the conclusion that the special processing was more trouble than benefit, at least when implemented on an ad hoc basis. IDA suggested to the Ada 9X ACVC Team that the process be considered when designing the Ada 9X test suite (i.e., that there be a means to efficiently implement this test-group processing).

IDA also responded to an implementer's query about a particular language rule which a few ACVC tests checked. In certain contexts with an access object A that accesses an array type, "A(1)" is illegal while the semantically equivalent "A.ALL(1)" is legal. The query was discussed with the FRT and the leader of the Ada 9X Mapping/Revision Team (MRT). The MRT is planning to revise the language definition to remove the peculiar case of legality that the ACVC tests check.

6. CONCLUSION

During this fiscal year, policy issues were effectively resolved through a consensus building process with compiler vendors, DoD, and non-DoD organizations. Not all members of the Ada community supported these changes but the objective of reducing the cost for validation during the period of transition to Ada 9X had been addressed. These costs will not disappear but will be incurred when a vendor responds to a Request for Proposal (RFP) for new business. DoD procurement officers are now requiring that the compiler version bid be tested in the exact computer system that is also bid. Conformity testing before contract award is becoming more common as vendors offer products that claim to comply with Federal Information Processing Standards (FIPS).

APPENDIX A.
SUMMARY OF FISCAL YEAR 1992 DISPUTED TESTS

A.1 CD2A51E, CD2A52A/E/F/I/J, CD2A54A/E/I/J (10 Tests)

These tests check that operations on a fixed point type are correct when the type is given the smallest possible size with a representation clause. One implementation rejected the length clause because the specified upper bound of the fixed-point type had been chosen as a "value of the type" and would not be able to be represented were the length clause obeyed. IDA accepted the petition against these tests on the basis of conflicting wording of the Ada standard and Commentaries, and also because the tests incorrectly test for the attributes 'FIRST and 'LAST.IDA cautioned the implementer to expect that these tests would likely be supported by the language revision (Ada 9X). (However, there has been no validation of an implementation exhibiting the behavior of this implementation.)

A.2 CD2A81A/B/E, CD2A83A/B/C/E (7 Tests)

These tests check that operations on an access type are correct when the type's size is specified with a representation clause. The standard customization of the ACVC allows only one size ("$ACC_SIZE") for access types. Some implementations use a larger size for access types whose designated type is STRING. The tests were modified by incrementing the macro-inserted specified size by a constant.

A.3 C34009D (1 Test)

This test checks operations on a derived record type with an array component; one check is that the record type's 'BASE'SIZE is greater than the sum of all of the components' 'SIZEs. Two petitioners have challenged this check for an implementation that includes only a pointer into the heap for the array component. Petitions on these points are accepted because ISO WG-9 is still deliberating the issue as Commentary AI-00825. However, one petitioner submitted an acceptable rationale with unacceptable implementation results. Many of the test's checks were failed in addition to the one that is

affected by AI-00825. This unsubstantiated petition was rejected, and later implementation results matched the previous, accepted petitions; the test was then allowed to be graded PASSED by Evaluation Modification (of ignoring the one failed check).

A.4 C34003A (1 Test)

This test checks that predefined operations are correctly implemented for derived floating-point types; it includes a check on the 'SIZE attribute. One implementation set FLOAT'SIZE to be 24, even though floating-point values in fact occupy 32 bits. The size of 24 was chosen because only floating-point operations could access one of the 4 bytes of a word. Essentially, the implementer was adapting an existing compiler to different hardware architecture, and considered the cost of re-implementing storage allocation in the compiler to be excessive. There was support for the petition on an AI-00325 basis, and the petition was accepted: the test was graded PASSED by Evaluation Modification (of ignoring the one failed check).

A.5 C35902A, CE3804J, CE3810B (3 Tests)

These tests make various checks, some of which depend on a implementation supporting fixed-point types of 32 bits. One implementation's fixed-point base type was of only 24 bits, where this was the largest integer size. For this implementation, C359032A was graded PASSED by a Test Modification: one constant was reduced in value to fit in 24 bits. CE3804J & CE3810B were graded INAPPLICABLE by Evaluation Modification (accepting the compiler's rejection of the too-large fixed-point type declarations).

A.6 C45521A-E (5 Tests)

These tests check floating-point operations. One implementation for the MIL-STD-1750A used hardware that had a bad floating-point division operation, which affected results on these tests. The FRT agreed that this implementer should not compensate for the bad machine instruction with a software implementation. These tests were graded PASSED by Evaluation Modification (of ignoring the failed checks on division).

A.7 CE3809A (1 Test)

This test checks that FLOAT_IO.GET operates correctly from strings. One petitioner argued that a bad machine floating-point division operation caused the

implementation's conversion routing to fail an accuracy check. The FRT was split on whether the implementation should compensate for the bad operation, but IDA rejected the petition. IDA favored the argument that the implementation's conversion routine should compensate for the bad hardware, just as user applications would have to do; it was not necessary that a routine be compromised by the bad hardware.

A.8 EE3301B (1 Test)

The IDA questioned this late petition as being incomplete, and subsequently the petitioner decided not to pursue the issue. IDA questioned the petition principally because only EE301B was cited, but IDA believed that EE3405B and EE3410F should also be affected. If these tests were not affected, further explanation of the petition seems necessary. In each of the three tests, test output that was written to STANDARD_OUTPUT is required to exhibit page breaks by explicit NEW_PAGE invocations in the unchallenged tests, and by output in excess of PAGE_LENGTH in EE3301B.

A.9 CE3801A/B (2 Tests)

These tests check that STATUS_ERROR is raised when TEXT_IO operations are attempted on unopened files; in separate blocks, calls are made to GET and PUT, each with the same actual parameter X. One petitioner argued that after the failed call to GET (STATUS_ERROR being raised, as expected), the parameter X was undefined because optimization had eliminated the previous assignment to X. As a consequence of the implementation's leaving X undefined, the following call to PUT raised CONSTRAINT_ERROR instead of STATUS_ERROR, and REPORT.FAILED is called. The petitioner cited passages from the Ada standard to support the assertion that X may (or even should) be undefined. The FRT generally did not find the petition compelling, but there was some sentiment that the behavior could be allowed in consideration of the lack of any good guidelines on what effects optimization may have. IDA ruled that the tests may be passed by the following Test, Processing, and Evaluation modifications: insert intervening assignments to X (between the GET and PUT operations) and process with full optimization; process the unmodified tests without optimization (and obtain normal PASSED results); and process the unmodified tests with optimization (to witness the behavior described by the petition). In fact, the petitioner changed the implementation and passed the tests without any modification.

APPENDIX B.
ACRONYM LIST

ACVC	Ada Compiler Validation Capability
AJPO	Ada Joint Program Office
AVF	Ada Validation Facility
IDA	Institute for Defense Analyses
FRT	Fast Reaction Team
ISO WG-9	International Organization for Standardization Working - Ada

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1992	Final

4. TITLE AND SUBTITLE
Ada Compiler Validation Support: Fiscal Year 1992

5. FUNDING NUMBERS
MDA 903 89 C 0003

Task Number T-D5-304

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Document D-1292

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Ada Joint Program Office
1211 South Fern Street, Rm C107
Arlington, VA 22202

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, unlimited distribution: 11 March 1994.

12b. DISTRIBUTION CODE
2A

13. ABSTRACT (Maximum 200 words)

This report summarizes the Ada compiler validation issues that had a bearing on policy changes incorporated in a revision of the Ada Compiler Validation procedures produced by the Institute for Defense Analyses, and published by the Ada Joint Program Office (AJPO) in August 1992. These policy changes include: (1) a time-limited (one year) provisional validation status for a compiler vendor who fails a small number (ten or fewer) conformity tests; (2) declaring that version 1.11 is the last version of the conformity test suite for the Ada 83 version of the language; and (3) providing guidelines for the use of an Ada compiler over the life of software development projects. This document also summarizes the nine test disputes resolved during FY92.

14. SUBJECT TERMS
Validation Status; Ada Compiler Validation Capability (ACVC); Ada 9X; Test Suite.

15. NUMBER OF PAGES
21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR